

## RECIRCULATING SAND FILTERS (RSF) DESIGN GUIDANCE

This document has been prepared by the Department of Environmental Protection to serve as a guide to the design of Recirculating Sand Filters. This is not intended to be a comprehensive design manual nor is it intended to restrict professional judgement in the design of RSFs but rather reflects accepted design criteria for a typical RSF. Deviations from the design parameters presented in this document can be allowed if scientifically and technically valid. The criteria described herein normally apply to larger systems (i.e. greater than 2,000 gallons per day); accordingly, certain changes in the design parameters may be necessary and desirable for smaller residential systems.

### I. PROCESS SUMMARY.

Recirculating sand filters (RSF) provide improved treatment of septic tank effluent over conventional soil absorption systems (SAS). Nationwide, high rates of failure have been associated with large conventional SAS; therefore RSFs are now required under Title 5 for systems with flows between 2,000 and 10,000 gallons per day located in nitrogen sensitive areas to help ensure proper treatment and longevity.

A typical RSF system consists of a septic tank, a recirculating tank and a sand filter. Operation of the system begins with primary treatment in the septic tank. The treated septic tank effluent then flows to the recirculating tank. In doses controlled by both a timer and a high level float switch, a mixture of fresh influent and recirculated, partially treated filtrate is applied to a sand filter bed of specified media. The wastewater is dispersed atop the media bed through a pressure distribution network. As the wastewater trickles downward through the sand/gravel media, pollutant reduction occurs as a result of biological treatment on the surface of the media particles.

The treated wastewater (filtrate) is collected at the bottom of the filter, and discharges, either by gravity or by pressure, to the recirculation tank. There it mixes with fresh influent from the septic tank. A portion of this mixture may be discharged to the leaching facility and the remainder recirculated to the sand filter where the cycle begins again. Different arrangements can be used to control recirculation and discharge. The final disposal of the treated wastewater is to an approved soil absorption system.

An important design factor in the sand filter dosing is the recirculation ratio (RR). The RR is defined as the ratio of the total flow through the sand filter to the forward (or average design) wastewater flow. Typical RR values for an RSF system range between 3:1 to 5:1. Besides determining the amount of wastewater to be pumped, the RR helps avoid odors by ensuring that the majority of wastewater applied to the sand filter is previously treated wastewater.

## I. DESIGN PROCEDURE

The design of the RSF system must require, at a minimum, the following steps:

1. Determine the average daily flow and wastewater strength based on influent criteria.
2. Determine the appropriate recirculation ratio. Generally, this ratio ranges between 3:1 and 5:1; however, certain designs may require different recirculation ratios.
3. Size the recirculating tank.
4. Size the sand filter based on the appropriate loading rate.
5. Size the recirculating pump(s) based on the recirculation ratio, average daily flow, desired pump cycle time, and the sand filter pressure distribution system (see **VI. WASTEWATER DISTRIBUTION CRITERIA**).
6. Size the final soil absorption system according to the loading rates and other pertinent design criteria described in Title 5.
7. Provide a bypass to allow direct discharge to the SAS if the sand filter fails. In systems over 2,000 gpd, an alarm should be provided to alert the system owner that the filter is being bypassed.

## II. INFLUENT CRITERIA

- A. Pre-treatment:** Wastewater applied to a recirculating sand filter must receive initial treatment in a septic tank designed in accordance with 310 CMR 15.221 and 15.223 through 15.229.
- B. Wastewater Strength - BOD<sub>5</sub>:** The recirculating sand filter is well suited for treating wastewater with higher concentrations of pollutants (such as BOD<sub>5</sub> and TSS) than normal household wastewater. Using BOD<sub>5</sub> as a wastewater strength indicator, the recirculating sand filter influent BOD<sub>5</sub> may be greater than 230 mg/l, but must be less than 720 mg/l.
- C. Wastewater strength measurements/estimates:**
  1. **Residential:** For residential applications the BOD<sub>5</sub> should be estimated to be 230 mg/l. For repair, alteration, or expansion, where the BOD<sub>5</sub> is suspected to exceed this figure due to expected pollutant loads or use of low flow devices, composite sampling is recommended. For new development where higher strength wastewater is anticipated (such as group home or institutional living situations), the BOD<sub>5</sub> shall be estimated on the basis of the best available comparative information.

2. **Non-Residential:** The repair, alteration or expansion of existing systems provides the opportunity for sampling and testing the project wastewater stream. Composite sampling is recommended. For new development the BOD<sub>5</sub> shall be estimated on the basis of the best available comparative information from similar facilities.

**D. Daily Wastewater Flow - design estimates:**

1. **Residential:** Residential wastewater design flows shall be 110 gallons per day per bedroom except that other specific residential flow estimates found at 310 CMR 15.203 may be substituted if appropriate.

2. **Non-Residential:** For non-residential applications a minimum wastewater design flow equal to 150% of the estimated daily flow should be used. Estimation of the daily flow should be based on the sewage flow design criteria at 310 CMR 15.203.

**E. Daily Wastewater Flow - actual:**

Accurate, site specific information about wastewater flows through an alternative system is often the most important piece of information in the assessment of operational problems. Designers are strongly encouraged to include influent flow measuring equipment in their designs.

#### **IV. RECIRCULATION RATIO**

The recirculation ratio (RR) is defined as the ratio of the total flow of the filter to the forward, or average design, flow. Common recirculation ratios fall within the range of 3:1 to 5:1. Generally a 5:1 RR is preferable. However, the designer should use experienced judgement in determining the appropriate RR. If the design engineer proposes an RR outside this range, appropriate documentation should be provided to justify the RR selected.

#### **V. RECIRCULATING TANK DESIGN CRITERIA**

The materials and construction requirements for the recirculation/mixing tank shall be in accordance with the provisions of 310 CMR 15.221. Appurtenances to the recirculating tank may include pumps, inlet and discharge piping, discharge valves, flow splitters or other necessary equipment for its proper function.

The tank volume shall be equal to the following (expressed in gallons).

1. For residential systems: 150% of the daily wastewater design flow.
2. For non-residential systems: 100% of the daily wastewater design flow.

**NOTE:** The apparent differences in these tank volume requirements is to adjust for the different way that residential and non-residential daily wastewater flow estimates are determined.

To encourage mixing of fresh influent with partially treated recirculating filtrate, the return line from the sand filter should enter the recirculating tank at the end opposite the pump location.

**Recirculating Pump:** The recirculating pump governs the recirculation ratio and dosing frequency. Daily dosing frequencies should be based on media grain size, wastewater strength and operating temperatures. Coarse media (> 0.45 mm) require frequent doses to ensure that sufficient wastewater residence time is provided in the filter. Also, stronger wastes will require more contact time with filter media and therefore must be dosed frequently. The frequency of dosing should allow for complete draining of the filter in order that the filter can be adequately reaerated. Based on typical design criteria, the recirculating pump should be controlled by a timer, in continuous cycles of 3 to 5 minutes on, 25 to 27 minutes off (for a total cycle time of 30 minutes). This dosing schedule provides 48 dosing periods per 24 hours, allowing a recirculation ratio of 3:1 to 5:1. The use of adjustable timers is recommended so that dosing schedules may be modified as site conditions warrant. Float switches are wired in parallel with the timer to control the pump during periods of excessive wastewater flows, and in event of timer malfunction. Both timer and float switch controls are required. If different recirculation ratios are used, the pump cycles and dosing periods should be adjusted accordingly.

The recirculating pump is sized based on the average daily flow, recirculation ratio, number of cycles, duration of each cycle and anticipated backflow (if any) per cycle. The following example illustrates typical calculations:

Assume:	1. Flow	2,000 gpd
	2. Number of doses	48 per day
	3. Doses duration	5 minutes
	4. Recirculation ratio	5:1
	5. Backflow per dose	10 gallons

(Note: The backflow per dose of 10 gallons is shown for illustrative purposes only. The actual backflow must be calculated based on pipe capacity and other relevant factors.)

$$\begin{aligned}\text{Total volume pumped} &= \text{Average daily flow} + \text{Recirculated flow} + \text{backflow} \\ &= 2,000 \text{ gpd} + (5 \times 2,000) + (48 \times 10) \\ &= 12,480 \text{ gpd}\end{aligned}$$

$$\begin{aligned}\text{Total pump run time} &= \text{Number of doses} \times \text{Dose duration} \\ &= 48 \times 5 \text{ min} \\ &= 240 \text{ min}\end{aligned}$$

$$\begin{aligned}\text{Pump flowrate} &= 12,480 \text{ gpd} / (240 \text{ min/day}) \\ &= 52 \text{ gpm}\end{aligned}$$

This flowrate is based on the recirculation requirements and must be checked against the flowrate required for pressure distribution in the sand filter. The higher flow requirement will govern pump selection.

Systems over 2,000 gpd will require at least two pumps in the recirculating tank. The pumps shall alternate, and all recirculating tanks, regardless of design flow, shall be equipped with high water level alarms which are to be wired to a circuit separate from the pumps.

**Discharge:** The recirculating tank shall be equipped with a discharge pipe to the final SAS. Typical designs may include a buoyant ball check valve, flow splitting box, discharge pump or equivalent arrangement which will allow an appropriate portion of wastewater to be discharged to the SAS after suitable treatment.

**VI. SAND FILTER LOCATION CRITERIA** - The minimum setback requirements for recirculating sand filters shall be same as those required for septic tanks in 310 CMR 15.210.

## **VII. FILTER BED AND DESIGN CRITERIA**

### **A. Filter Bed Containment:**

The filter bed shall be constructed in either a concrete container meeting the design specifications at 310 CMR 15.221 or a synthetic membrane-lined pit. The top of the containment structure shall extend to natural grade or above. If above natural grade, final grading shall bring fill up to the top of wall. In either case, the containment structure shall be adequately protected from the elements. If the sand filter is proposed to be enclosed, provisions shall be made for adequate venting and access for inspection and maintenance purposes. If the sand filter is not proposed to be enclosed, sufficient cover material to provide insulation and protection from the elements will be required.

Distribution piping shall sit atop the sand media. Single orifices shall be placed at the 5 and 7 o'clock positions in an alternating fashion and perforations between adjacent laterals should be staggered to provide more uniform distribution. The sand media shall have a minimum effective depth of 24 inches. Collection piping shall sit at the bottom of the containment structure and be covered with 6" of 3/4" to 1-1/2" stone with a 2" layer of pea gravel (1/8" to 1/2" stone) between this stone layer and the filter sand media. All stone shall be washed and less than 1% by weight shall pass a #200 sieve.

### **B. Media Specifications:**

1. Filter media must meet the particle size criteria detailed below based upon a particle size analysis of the actual sand/gravel material proposed for use. This analysis must be performed according to standard testing methods. Each load of media used in constructing the sand filter shall be sieve tested in order to assure compliance with filter media specifications:

- a. Effective Size: 1 mm to 2 mm
- b. Uniformity coefficient: less than or equal to 3.0
- c. Filter media must be washed and less than 1% by weight shall pass a #200 sieve.

If the design engineer proposes to utilize media which do not meet these criteria, appropriate documentation shall be provided to justify the media selection.

### C. **Filter Bed Sizing:**

**1. Loading Rate (LR):** shall be calculated on the basis of the BOD<sub>5</sub> of the septic tank effluent. Repair, alteration, and expansion projects provide the opportunity to sample and test the actual wastewater. (Composite sampling is recommended.) New sites must rely on wastewater strength estimates from similar facilities. The following rate shall be calculated as follows:

$$\text{LR (expressed as GPD/SQ.FT)} = \frac{1150}{\text{BOD}_5 \text{ of septic tank effluent}}$$

For residential applications, the loading rate typically ranges between 3.0 to 5.0 gpd/ft<sup>2</sup>. The loading rate will be less than 5.0 gpd/ft<sup>2</sup> if it is known or suspected that the BOD<sub>5</sub> of a particular wastewater is greater than 230 mg/l.

**2. Surface Area of Filter Bed (SA):** shall be determined by dividing the wastewater design flow (in gpd), by the loading rate (in gpd/ft<sup>2</sup>).

$$\frac{\text{Wastewater design flow (gpd)}}{\text{LR (gpd/ft}^2\text{)}} = \text{SA (ft}^2\text{.)}$$

**3. Depth (thickness) of media gravel:** should range between 24 and 36 inches.

### D. **Filter bypass:**

The sand filter shall be designed with a bypass that allows for direct discharge to the SAS should the filter clog and ponding occur on the filter surface. The bypass should be designed to allow minimal ponding and an alarm should be provided in systems over 2,000 gpd to alert the system owner of the bypass condition.

## **VIII. WASTEWATER DISTRIBUTION CRITERIA**

Influent to the sand filter shall be evenly distributed to the sand filter by a pressure distribution system designed in accordance with the Department Guidelines For Pressure Distribution. This also applies to any pumps, sumps, controls, and any other pressure distribution-related components.

## **IX. TREATED WASTEWATER (Filtrate) COLLECTION & DISCHARGE -**

Filtrate may be collected and discharged from the bottom of the sand filter by either a gravity-flow underdrain system, or a pumped flow pumpwell system.

- A. Sand Filter to Recirculating Tank Pipe Sizing** - Sizing the pipe from the sand filter to the mixing/recirculating tank can be done using the Hazen-Williams equation, which relates flow, pipe diameter, slope, and pipe smoothness. Typically, it is expressed in the following manner:

$$S = ((2.31 \times Q)/(C \times d^{2.63}))^{1.852} \text{ where}$$

S = slope of energy gradient, in feet/foot

Q = flow, in cubic feet per second

C = dimensionless smoothness coefficient (typically C=150 for PVC pipe)

d = inside diameter of pipe, in feet

Rearranging this equation and multiplying by 12, provides an equation to calculate the appropriate pipe diameter, in inches, for the gravity flow underlain pipe and filter-to-recirculating-tank transport pipe. It is also the size (inlet & outlet diameters) of the buoyant-ball check valve.

$$d \text{ (inches)} = 12((2.31 \times Q)/(C \times S^{0.54}))^{0.38}$$

## **X. POST-SAND FILTER EFFLUENT DISPOSAL CRITERIA -**

Recirculating sand filter effluent (filtrate) must be discharged to a subsurface soil absorption system either by gravity or by a pressure distribution in accordance with 310 CMR 15.211, 15.212 and 15.240 through 15.255.

## **KI. MANAGEMENT, OPERATION & MAINTENANCE**

### **MANAGEMENT**

The approving authority shall require that an acceptable maintenance agreement be established, and supporting documents be developed and approved by the approving authority, prior to the issuance of approvals for a proposed RSF system. Any such maintenance agreement shall be with:

1. A licensed wastewater treatment plant operator of sufficient grade;
2. A company providing contract operations of wastewater treatment facilities employing licensed wastewater treatment plant operators of sufficient grade; or
3. If a commercial facility, an employee possessing a wastewater treatment plant operator's license of sufficient grade.

### **OPERATION -- USER'S MANUAL**

A user's manual for the RSF system shall be provided by the system designer at the time of application and must be approved prior to the issuance of the Certificate of Compliance. These materials shall contain at a minimum the following:

1. Diagrams of the system components and their location.
2. Explanation of general system function, operational expectations, owner responsibility, etc.
3. Specifications of all electrical and mechanical components installed (occasionally components other than those specified on the plans are used).
4. Names and telephone numbers of the system designer, approving authority, component manufacturer, supplier/installer, and the management entity and regulatory authority to be contacted in the event of a failure.
5. Information on the periodic maintenance requirements of the sewage system: septic tank, dosing and recirculating tanks, sand filter unit, pumps, switches, alarms, disposal unit, etc.
6. Information on "Trouble-shooting" common operational problems that might occur. This information should be as detailed and complete as needed to assist the system owner make accurate decisions about when and how to attempt corrections of operational problems, and when to call for professional assistance.
7. Information on the safe disposal of discarded filter media (open sand filter only).



8. For proprietary sand filter devices, a complete maintenance and operation document shall be developed and provided by the manufacturer. This document shall be made available, through the system designer, to the system owner. This document shall include all the appropriate items mentioned above, plus any additional general and site-specific information useful to the system owner, and/or the maintenance person. A copy of this document shall also be provided to the approving authority and the Department, prior to the issuance of the disposal system construction permit.

## **MAINTENANCE**

For the on-site treatment and disposal system to operate properly, its various components need periodic inspection and maintenance by the system owner. In addition to the following recommended maintenance description and schedule, the approving authority may specify additional requirements.

1. Septic tank:
  - a. for systems with a design flow greater than or equal to 2000 gpd, annual inspection and pumping;
  - b. for systems with a design flow less than 2000 gpd, annual inspection with pumping required at least once every three years.
2. Dosing and Recirculating tanks: rinse the effluent screen (spray with hose), inspect and clean the pump switches and floats yearly. Pump the accumulated sludge from the bottom of the chambers, whenever the septic tank is pumped, or every three years, whichever is sooner.
3. Pumpwell: pump the accumulated sludge from the bottom of the pumpwell, whenever the septic tank is pumped, or every three years, whichever is sooner.
4. Pump switches, floats, alarm system: inspect and test yearly, and repair as needed.
5. Pump and pump screen: inspect yearly and clean as needed.
6. Recirculation Sand Filter/Exposed-surface filter bed: weed and remove debris from the bed surface quarterly.

## **XII. PERFORMANCE MONITORING**

- A. Performance monitoring is required on sand filters permitted under 310 CMR 15.000.
- B. For systems over 2,000 gpd the frequency of monitoring shall be:
  1. quarterly (every 3 months) following installation, and
  2. at time of problems, complaints or failure.

After five years of monitoring, the Department shall review the performance data and determine if further long-term monitoring should be required.

For systems under 2,000 gpd, monitoring frequency and duration shall be determined on a case-by-case basis.

- C. The minimum criteria that should be addressed in performance monitoring of sand filters are:
1. Type of use;
  2. Age of system;
  3. Nuisance factors, such as odors or user complaints;
  4. Malfunction of electrical equipment such as timers, counters, control boxes, or other electrical components;
  5. Material fatigue, failure, corrosion problems, or use of improper materials, as related to construction or structural design;
  6. Neglect or improper use, such as loading beyond the design rate, poor maintenance, or excessive weed growth;
  7. Installation problems, such as improper location or failure to follow design;
  8. Septic tank maintenance, including pumping frequency, structural integrity, ground water intrusion, or improper sizing;
  9. Pump chamber maintenance, including improper or inadequate maintenance, infiltration, structural problems, or improper sizing;
  10. Overflow or backflow problems where sewage is involved;
  11. Pump malfunctions including problems related to dosing volume, pressurization, breakdown, clogging, burnout, or cycling;
  12. Switch malfunctions, as related to pump controls and alarm controls, such as improper setting or failure, of electrical, mechanical, or manual switches; and
  13. Specific chemical/biological indicators, such as BOD, TSS, fecal or total coliforms, etc. Sampling and testing may be required by the local Board of Health on a case-by-case basis, depending on the nature of the problems, availability of laboratories, or other factors.

- D. Forms for the collection of monitoring data, as well as management of the alternative system database, will be provided by the Department as required by conditions set forth in the Certificate of Compliance.
- E. Completed forms/reports shall be submitted to the Department.